

# Relation of energy, fat, and fiber intakes to plasma concentrations of estrogens and androgens in premenopausal women<sup>1,2</sup>

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**ABSTRACT** To evaluate whether diet may influence the incidence of hormone-dependent cancers through an effect on blood estrogen and androgen concentrations, we analyzed diet-blood hormone relations in a cross-sectional study. Dietary energy, fat, and fiber intakes were estimated from 7-d food records completed by 90 premenopausal women on days 14–20 of their menstrual cycles. Fasting blood specimens were collected on days 5–7, 12–15, and 21–23 of each participant's cycle and pooled to create follicular-, midcycle-, and luteal-phase samples, respectively, for analysis. Energy intake was associated inversely with plasma androstenedione and dehydroepiandrosterone sulfate (DHEAS), averaged across the three menstrual cycle phases, and directly with the probability of a luteal-phase rise in progesterone. For each additional 1 MJ (239 kcal) consumed, androstenedione decreased by 6.0% (95% CI: -8.4%, -3.6%), DHEAS decreased by 5.1% (95% CI: -9.6%, -0.4%), and the probability of a progesterone rise increased by 60% (95% CI: 5%, 145%). After energy intake was adjusted for, the ratio of polyunsaturated to saturated fat (P:S) in the diet was significantly inversely associated with plasma estradiol and estrone during the luteal phase of the menstrual cycle. For each 0.1 increment in the P:S, there was a 7.6% (95% CI: -14.3%, -0.5%) decrease in estradiol and a 6.8% (95% CI: -12.7%, -0.6%) decrease in estrone. Results of this cross-sectional study support a relation between both energy and fat ingestion and plasma sex hormone concentrations in premenopausal women. *Am J Clin Nutr* 1996;64:25–31.

**KEY WORDS** Diet, energy intake, dietary fats, dietary fiber, diet records, estrogens, androgens

## INTRODUCTION

International correlations between dietary fat and cereal consumption and cancer mortality suggest a role for diet in the etiology of breast and other hormone-dependent cancers (1). Results from studies on individuals, however, have been inconsistent. Direct associations with fat intake (2–11) and inverse associations with fiber intake (2, 5, 12–14) for breast cancer have been reported by some investigators but not by others (15–24).

Blood estrogens (25–30) and androgens (31–37) have been reported to be elevated in women with breast cancer, and diet

has been hypothesized to affect breast cancer risk through blood hormone concentrations (38, 39). Hormonal profiles of vegetarians reportedly differ from those of omnivores (40–43), but findings for specific hormones are inconsistent. Intervention studies also have yielded conflicting results about the relation of diet to blood estrogens and androgens in premenopausal women (44–52).

As part of a cross-sectional study of plasma hormones in premenopausal women, 90 women completed 7-d diet records. We analyzed these data to explore relations of energy, fat, and fiber intakes to plasma estrogens and androgens during three phases of the menstrual cycle.

## SUBJECTS AND METHODS

Participants in the cross-sectional study were recruited by posters and newspaper advertisements from communities around Beltsville, MD, during 1988–1990. The protocol was approved by the National Institutes of Health (NIH) Clinical Center Institutional Review Board–National Cancer Institute Clinical Research Subpanel and Georgetown University School of Medicine Institutional Review Board. Only women who met the following criteria were eligible: 1) 21–40 y of age; 2) premenopausal with a usual cycle length of  $\leq 35$  d; 3) no history of cancer, diseases of the reproductive or endocrine systems, chronic liver or gastrointestinal disease, hypertension, diabetes, nephrolithiasis, gout, or hyperlipidemia; 4) not pregnant or lactating during the previous 12 mo and not taking oral contraceptives during the previous 6 mo; 5) weight-for-height 85–130% of desirable based on 1983 Metropolitan Life Insurance

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ance tables (53); 6) no history of alcohol abuse; 7) not taking any medications other than an occasional analgesic; 8) not following a vegetarian diet; 9) not routinely participating in strenuous activities; and 10) not smoking. Because the study's primary objective was to evaluate the association of alcohol ingestion with plasma hormones, women with a wide range of drinking patterns were recruited.

All data and blood specimens were collected during a single menstrual cycle during which participants were asked to maintain their usual diets. Dietary data were collected by using 7-d records, and before data collection began participants were trained by a research dietitian to complete these records. Measuring cups and spoons, scales, and drawings were provided to participants for use in estimating portion sizes. Participants recorded all foods and beverages they consumed daily, from menstrual cycle day 14 through day 20, and a trained on-site dietitian reviewed each day's records on the following workday. The 7-d dietary records were analyzed by using version 19 of the University of Minnesota Nutrition Coordinating Center's database (54). The database included 1367 food items with values for energy, fat, and dietary fiber for virtually all foods, although saturated and polyunsaturated fatty acid values were imputed for approximately one-third and dietary fiber was imputed for approximately one-half of the items (M Stevens, personal communication, 1996).

Blood was collected in the morning after an overnight fast. Equal volumes of plasma from days 5 to 7, 12 to 15, and 21 to 23 of the menstrual cycle were pooled for each individual to create follicular-, midcycle-, and luteal-phase specimens, respectively. All plasma specimens were stored at  $-70^{\circ}\text{C}$  until the hormones were analyzed. Estrone, estradiol, and androstenedione in plasma were measured by radioimmunoassay after solvent extraction and celite chromatography (55). Estrone sulfate was also measured by radioimmunoassay after solvolysis, extraction of hydrolyzed estrone, and celite chromatography (55). Dehydroepiandrosterone sulfate (DHEAS) and progesterone were measured with radioimmunoassay kits (ICN-Biomedical, Costa Mesa, CA) and sex-hormone-binding globulin (SHBG) was measured with an immunoradiometric assay kit (Famos Group Ltd, Oulunsalo, Finland). The percentages of unbound and albumin-bound estradiol were measured by using centrifugal ultrafiltration (56), and SHBG-bound estradiol was calculated. Between-batch CVs for replicate quality-control samples were 18.5% for estrone, 22.0% for estradiol, 6.4% for estrone sulfate, 31.7% for androstenedione, 19.3% for DHEAS, 13.2% for progesterone, 25.6% for SHBG, and 15.8% for percentage unbound and 12.6% for percentage albumin-bound estradiol. Within-batch CVs for the same samples were substantially lower: 3.5% for estrone, 4.4% for estradiol, 2.7% for estrone sulfate, 8.1% for androstenedione, 6.3% for DHEAS, 8.3% for progesterone, 10.9% for SHBG, and 7.3% for percentage unbound and 5.8% for percentage albumin-bound estradiol.

A total of 107 women participated in the cross-sectional study and 99 completed 7 d of diet records between mid-October and early April. Because we were interested in usual diet and because holidays can affect dietary patterns, data collection was discontinued over the Christmas and New Year holidays and eight women who completed records over Thanksgiving were dropped from analysis. One woman with an

extreme P:S also was dropped, leaving a total of 90 women with dietary data for analysis.

In an earlier analysis of these hormone data (57), we found high correlations across menstrual cycle phases for plasma androstenedione, DHEAS, and SHBG; Pearson correlations ranged from 0.72 to 0.94. Therefore, instead of analyzing diet associations by menstrual cycle phase, concentrations of androstenedione, DHEAS, and SHBG for the follicular, midcycle, and luteal phases were averaged and their mean values were used in the current analysis.

Linear regression was used to evaluate the relation of diet to plasma hormone concentrations, and logistic regression was used to evaluate the relation of diet to the probability of a rise in progesterone during the luteal phase (58). All plasma hormone concentrations were converted to the  $\log_{10}$  scale before analysis to improve normality. Energy, fat, and fiber were modeled as both continuous variables and categorical variables that defined quartiles of intake. Findings were generally comparable regardless of the method used to define dietary intake. Results of continuous models are reported in detail with results of categorical analysis described in the text only when they differed. All models included age as a continuous variable and hormone analysis batch as a set of categorical dummy variables; models to test associations with fat and fiber included total energy intake. In earlier analyses of these data, the following were the only significant associations observed between participant characteristics and plasma hormone concentrations: 1) follicular-phase plasma estradiol with height (59), 2) midcycle- and luteal-phase plasma estradiol with parity (60), 3) midcycle- and luteal-phase plasma estrone sulfate with age at first birth (60), 4) androstenedione with alcohol ingestion (57), and 5) plasma SHBG with weight (59). Each covariate was included in models for the specific hormone with which it was associated previously. All analyses were performed by using SAS Statistical Software (61).

## RESULTS

Demographic and anthropometric characteristics of participants in this cross-sectional study were reported previously (57). Briefly, the 90 women who completed diet records were  $29.5 \pm 5.2$  y ( $\bar{x} \pm \text{SD}$ ) of age. Their mean height and weight were  $165.4 \pm 6.6$  cm and  $63.2 \pm 11.4$  kg, respectively, and their mean body mass index (in  $\text{kg}/\text{m}^2$ ) was  $23.1 \pm 4.1$ . Eighty-two women (92%) reported regular menstrual cycles during the past year and their usual cycle length was  $28.5 \pm 2.1$  d. All of the women had completed  $\geq 12$  y of school.

As shown in **Table 1**, the women consumed an average of 8.5 MJ (2032 kcal)/d with a mean ( $\pm \text{SD}$ ) of  $36.4 \pm 5.8\%$  of

**TABLE 1**  
Daily intakes of energy, fat, and fiber<sup>1</sup>

Energy (MJ)	8.5 $\pm$ 2.0
Total fat (g)	83.5 $\pm$ 24.1
Saturated fatty acids (g)	30.5 $\pm$ 9.2
Polyunsaturated fatty acids (g)	16.3 $\pm$ 5.7
Monounsaturated fatty acids (g)	30.8 $\pm$ 9.2
P:S	0.58 $\pm$ 0.14
Dietary fiber (g)	16.0 $\pm$ 6.8

<sup>1</sup>  $\bar{x} \pm \text{SD}$ ;  $n = 90$ . P:S, ratio of polyunsaturated to saturated fatty acids.

energy provided by fat,  $48.3 \pm 7.0\%$  by carbohydrate,  $14.2 \pm 2.0\%$  by protein, and the remainder by alcohol. Saturated fatty acids contributed  $13.3 \pm 2.4\%$  of energy whereas polyunsaturated fatty acids contributed  $7.0 \pm 1.6\%$ . The P:S of the diet averaged  $0.6 \pm 0.1$ . The distribution of alcohol intake was highly skewed; during the week they completed their diaries, 14 (16%) of the women reported no alcohol ingestion from foods or beverages, 20 (22%) consumed  $< 12.0$  g, 20 (22%) consumed 12.0–47.9 g, 18 (20%) consumed 48.0–107.9 g, and 18 (20%) consumed  $\geq 108.0$  g. For reference, an average serving of beer, wine, or liquor contains 12 g alcohol.

The plasma estrogen concentrations of the subjects during each menstrual cycle phase are presented in **Table 2**. For the three phases of the menstrual cycle combined, the geometric mean ( $\pm$  SD) concentrations of androstenedione, DHEAS, and SHBG were  $9.0 \pm 1.4$  nmol/L,  $7.5 \pm 1.6$   $\mu$ mol/L, and  $38.6 \pm 1.5$  nmol/L, respectively.

Associations of energy, fat, and fiber intakes with plasma hormone concentrations are shown in **Tables 3** and **4**. After adjustment for age, hormone analysis batch, and other covariates as described in Methods, energy intake was not associated with plasma concentrations of the estrogens or SHBG but was associated with plasma concentrations of the androgens, androstenedione, and DHEAS, averaged over the three phases of the menstrual cycle. For each additional 1 MJ (239 kcal) of energy consumed daily, there was a significant ( $P = 0.0001$ ) 6.0% decrease (95% CI:  $-8.4\%$ ,  $-3.6\%$ ) in plasma androstenedione and a significant ( $P = 0.04$ ) 5.1% decrease (95% CI:  $-9.6\%$ ,  $-0.4\%$ ) in the plasma DHEAS concentration.

Total energy intake was included in models to test the relations of fat and fiber with plasma hormones. Hormone concentrations were not related to total fat or saturated fatty acid ingestion. Polyunsaturated fatty acid intake, however, was significantly ( $P = 0.03$ ) positively associated with follicular-phase plasma estrone sulfate and significantly ( $P = 0.05$ ) inversely associated with luteal-phase plasma estrone. For each additional 1 g of polyunsaturated fatty acids consumed daily, luteal-phase estrone decreased by 2.1% (95% CI:  $-4.1\%$ ,  $-0.1\%$ ). Luteal-phase plasma estradiol also decreased by 2.1% (95% CI:  $-4.4\%$ ,  $0.3\%$ )/g polyunsaturated fatty acids, and the association was marginally significant ( $P = 0.09$ ). Luteal-phase plasma estradiol and estrone were both significantly inversely associated with the P:S of the diet ( $P \leq 0.04$ ), which ranged from 0.3 to 0.9. For each 0.1 increment in the P:S, plasma estradiol and estrone decreased by  $\approx 7\%$  during the luteal phase of the menstrual cycle. Conversely, for an equivalent change in the P:S, the plasma DHEAS concentration averaged over the three phases of the menstrual cycle increased significantly by almost 10% ( $P = 0.01$ ).

**TABLE 2**

Plasma estrogen concentrations by menstrual cycle phase<sup>1</sup>

	Follicular	Midcycle	Luteal
	pmol/L		
Estradiol	$139.4 \pm 1.6$	$251.3 \pm 1.7$	$250.4 \pm 1.7$
Estrone	$208.0 \pm 1.5$	$321.0 \pm 1.5$	$310.8 \pm 1.5$
Estrone sulfate	$1402 \pm 1.6$	$2473 \pm 1.8$	$2276 \pm 1.8$

<sup>1</sup> Geometric mean  $\pm$  SD;  $n = 90$ .

Diet-estradiol associations did not differ substantially among the fractions of estradiol that were free, albumin-bound, or SHBG-bound. In general, results reported in **Tables 3** and **4** also were similar when we analyzed dietary variables after categorizing individuals into quartiles. A 28.7% lower (95% CI:  $-46.9\%$ ,  $-4.3\%$ ) plasma SHBG concentration among women in the highest compared with the lowest quartile of polyunsaturated fat consumption was the only significant association observed by using categorical rather than continuous dietary variables for analysis ( $P = 0.03$ ). The direct association of polyunsaturated fatty acid intake with follicular-phase plasma estrone sulfate, however, was not evident and the inverse association of energy intake with DHEAS was less clear on the basis of categorical dietary variables.

Thirteen women (14%) did not have a progesterone rise  $\geq 9.54$  nmol/L (3 ng/mL) during the luteal phase of their menstrual cycle, indicating that the cycle was anovulatory or that days 21–23 were not truly midluteal. Energy intake was significantly positively associated with the likelihood of a progesterone rise ( $P = 0.03$ ); consumption of an additional 1 MJ (239 kcal) daily increased the odds by 60% (95% CI: 5%, 145%). Fat and fiber were not associated with the probability of a progesterone rise.

When we restricted analysis to women who had had a progesterone rise, diet-hormone relations did not differ markedly from those reported in **Tables 3** and **4**. The only notable differences were the associations of luteal-phase plasma estrone with polyunsaturated fatty acid intake and P:S were slightly diminished and no longer significant at  $P \leq 0.05$ . The difference per 1 g of polyunsaturated fatty acid intake was  $-1.8\%$  (95% CI:  $-4.0\%$ ,  $0.4\%$ ) and the difference per 0.1 increment in the P:S was  $-5.6\%$  (95% CI:  $-12.6\%$ ,  $2.0\%$ ). The marginally significant association of energy ingestion with SHBG ( $P = 0.08$ ), on the other hand, was slightly stronger (difference = 5.1%; 95% CI: 0.3%, 10.0%) and significant when analysis was restricted to women who had a rise in luteal-phase progesterone ( $P = 0.04$ ). Additionally, the SHBG concentration was significantly inversely associated with the P:S of the diet (difference =  $-7.1\%$ ; 95% CI:  $-13.5\%$ ,  $-0.2\%$ ).

## DISCUSSION

Results of this cross-sectional study indicate that premenopausal women with higher energy intakes have lower plasma concentrations of androstenedione and DHEAS averaged across the menstrual cycle but are more likely to have a rise in progesterone during the luteal phase consistent with ovulation. Results also suggest inverse associations of polyunsaturated fat and the P:S with plasma concentrations of estradiol and estrone during the luteal phase of the menstrual cycle.

Dietary fat and fiber have been hypothesized to modify breast cancer risk by elevating and depressing plasma hormone concentrations, respectively (38, 39). Compared with omnivores, premenopausal vegetarian women have been reported to have significantly lower estradiol and estrone concentrations during the luteal phase of the menstrual cycle (41) and nonsignificantly lower concentrations of these hormones during the follicular phase (40). Vegetarians and nonvegetarians differ for many characteristics other than diet, and differences in hormone concentrations cannot be attributed solely to diet. In a controlled study in which

TABLE 3

Plasma estrogen concentrations by menstrual cycle phase, related to increasing daily energy intake by 1 MJ and daily fat and fiber intakes by 1 g<sup>1</sup>

	Follicular	Midcycle	Luteal
	% difference		
Estradiol (pmol/L)			
Energy (MJ)	-1.73 (-6.29, 3.06)	2.98 (-2.72, 9.03)	3.38 (-1.75, 8.77)
Total fat (g)	0.56 (-0.12, 1.24)	-0.24 (-1.08, 0.60)	-0.22 (-0.96, 0.53)
Saturated fatty acids (g)	1.38 (-0.31, 3.09)	-0.72 (-2.75, 1.36)	0.50 (-1.33, 2.38)
Polyunsaturated fatty acids (g)	1.73 (-0.48, 3.99)	-0.56 (-3.22, 2.19)	-2.09 (-4.40, 0.27)
Monounsaturated fatty acids (g)	0.92 (-0.74, 2.61)	-0.28 (-2.31, 1.80)	-0.46 (-2.27, 1.38)
P:S <sup>2</sup>	-0.11 (-6.92, 7.19)	-0.10 (-8.33, 8.87)	-7.63 <sup>3</sup> (-14.27, -0.49)
Dietary fiber (g)	-0.15 (-1.77, 1.51)	1.08 (-0.90, 3.11)	1.49 (-0.27, 3.28)
Estrone (pmol/L)			
Energy (MJ)	-2.49 (-6.22, 1.38)	2.15 (-2.11, 6.60)	1.85 (-2.54, 6.44)
Total fat (g)	0.33 (-0.24, 0.90)	-0.35 (-0.96, 0.27)	-0.15 (-0.79, 0.50)
Saturated fatty acids (g)	0.66 (-0.75, 2.09)	-0.59 (-2.12, 0.95)	0.34 (-1.25, 1.97)
Polyunsaturated fatty acids (g)	0.65 (-1.20, 2.53)	-0.87 (-2.85, 1.16)	-2.10 <sup>3</sup> (-4.08, -0.07)
Monounsaturated fatty acids (g)	0.84 (-0.54, 2.23)	-0.87 (-2.35, 0.63)	-0.03 (-1.58, 1.55)
P:S <sup>2</sup>	1.26 (-4.52, 7.39)	-0.79 (-6.97, 5.79)	-6.84 <sup>3</sup> (-12.67, -0.62)
Dietary fiber (g)	-0.56 (-1.90, 0.79)	0.73 (-0.75, 2.23)	0.18 (-1.35, 1.74)
Estrone sulfate (μmol/L)			
Energy (MJ)	2.07 (-3.76, 8.26)	2.78 (-4.39, 10.48)	-1.30 (-8.20, 6.11)
Total fat (g)	0.55 (-0.31, 1.41)	0.00 (-1.02, 1.04)	0.14 (-0.89, 1.18)
Saturated fatty acids (g)	0.61 (-1.52, 2.78)	-0.39 (-2.90, 2.18)	0.39 (-2.14, 2.99)
Polyunsaturated fatty acids (g)	3.17 <sup>3</sup> (0.40, 6.01)	0.82 (-2.49, 4.24)	0.33 (-2.98, 3.74)
Monounsaturated fat (g)	0.67 (-1.41, 2.79)	-0.20 (-2.67, 2.33)	0.12 (-2.36, 2.67)
P:S <sup>2</sup>	5.34 (-3.53, 15.03)	1.55 (-8.60, 12.84)	-0.99 (-10.92, 10.04)
Dietary fiber (g)	-1.22 (-3.21, 0.82)	-0.20 (-2.61, 2.27)	-0.82 (-3.22, 1.63)

<sup>1</sup> *n* = 90; 95 CIs in parentheses. Estimates from linear-regression models including age, hormone analysis batch, and energy intake. P:S ratio of polyunsaturated to saturated fatty acids. Follicular-phase estradiol concentrations were adjusted for height, midcycle and luteal-phase estradiol concentrations were adjusted for parity; and midcycle and luteal phase concentrations of estrone sulfate were adjusted for age at first birth.

<sup>2</sup> Estimates are for a change of 0.1.

<sup>3</sup> *P* ≤ 0.05.

individuals were randomly assigned to a standard nonvegetarian diet, a vegetarian diet, or a vegetarian diet plus fish. Bennett and Ingram (62) found that after 3 mo, women on the vegetarian diet, but not on the standard or fish diets, had marginally significantly decreased concentrations of estradiol during the luteal phase of the menstrual cycle.

Results of intervention studies with dietary fat and fiber also suggest that diet may influence luteal-phase blood estradiol concentrations. Luteal-phase estradiol was decreased in women on a low-fat and/or high-fiber diet in three studies (44–46). In a fourth study conducted under controlled dietary conditions, estradiol was decreased in women on a low-fat diet with a P:S

TABLE 4

Plasma concentrations of androstenedione, DHEAS, and SHBG related to increasing daily energy intake by 1 MJ and daily fat and fiber intakes by 1 g<sup>1</sup>

	Androstenedione (nmol/L)	DHEAS (μmol/L)	SHBG (nmol/L)
	% difference		
Energy (MJ)	-6.03 <sup>2</sup> (-8.38, -3.61)	-5.12 <sup>3</sup> (-9.64, -0.36)	3.92 (-0.41, 8.44)
Total fat (g)	-0.10 (-0.49, 0.29)	-0.07 (-0.78, 0.65)	-0.23 (-0.85, 0.40)
Saturated fatty acids (g)	-0.26 (-1.22, 0.72)	-0.90 (-2.64, 0.87)	0.20 (-1.31, 1.74)
Polyunsaturated fatty acids (g)	-0.08 (-1.35, 1.21)	1.30 (-1.02, 3.67)	-1.37 (-3.36, 0.66)
Monounsaturated fatty acids (g)	-0.27 (-1.21, 0.67)	-0.21 (-1.93, 1.54)	-0.71 (-2.21, 0.82)
P:S <sup>4</sup>	2.00 (-1.99, 6.16)	9.79 <sup>5</sup> (2.29, 17.84)	-4.12 (-9.92, 2.06)
Dietary fiber (g)	0.66 (-0.26, 1.60)	0.98 (-0.72, 2.71)	0.94 (-0.55, 2.45)

<sup>1</sup> *n* = 90; 95 CIs in parentheses. Estimates from linear regression models including age, hormone analysis batch, and energy intake. DHEAS, dehydroepiandrosterone sulfate; SHBG, sex-hormone-binding globulin. Androstenedione and SHBG values were adjusted for alcohol ingestion and weight, respectively.

<sup>2</sup> *P* ≤ 0.0001.

<sup>3</sup> *P* ≤ 0.05.

<sup>4</sup> Estimates are for a change of 0.1.

<sup>5</sup> *P* ≤ 0.01.

of 0.3 but not in women on a low-fat diet with a P:S of 1.0 (47). In two other studies, however, no difference in luteal-phase estradiol was reported when women were changed to a low-fat and/or high-fiber diet (48, 49). Luteal-phase estrone was reported to be decreased in women eating a low-fat diet in one study (44) but not in another (46).

Goldin et al (50) found that women fed a low-fat, high-fiber diet under controlled conditions had lower estradiol, estrone, and estrone sulfate serum concentrations during the follicular phase of the menstrual cycle. Although these findings for estrone sulfate are supported by results of one other study (51), intervention studies generally do not support an association of dietary fat and/or fiber with follicular-phase serum estrone (49, 51) or estradiol (47, 49, 51).

The role of diet in modifying blood androgens in premenopausal women has been studied less extensively. Goldin et al (50) reported lower testosterone and androstenedione concentrations in women consuming a low-fat, high-fiber diet, but Woods et al (51) and Ingram et al (48) did not observe associations of these androgens with diet. Similarly, although DHEAS was reported to be depressed in women consuming a low-fat diet in one study (52), there was no effect of diet on DHEAS in a second study (48). SHBG concentrations of premenopausal women were modified by diet in one study (50), but no association was observed in three other studies (48, 51, 63).


In the intervention studies summarized above, the diet-hormone associations reported clearly reflected the effect of diet on hormones. In our study, however, which used a cross-sectional design, the direction of the observed associations is unclear. Energy ingestion has been reported to be higher during the luteal than follicular phase of the menstrual cycle by some investigators (64–66) but not by others (67–69). This variation in energy ingestion has been hypothesized to be due to changes in blood estrogen or progesterone concentrations (65). The positive association that we observed between energy intake and the probability of a rise in luteal-phase progesterone, therefore, could have been due to an effect of progesterone on energy consumption rather than the reverse. Tangney et al (69) and Abraham et al (70) also reported significant fluctuations in fat intake over the menstrual cycle, but in three other studies no significant variation was detected (68, 69, 71). None of these studies reported results for type of fat or for the P:S of the diet.

Frequently, multiple diet records are used as the standard against which other dietary data collection tools are evaluated. Because of their greater ease of administration, however, food-frequency questionnaires are generally the method of choice for large-scale epidemiologic investigations. As part of this cross-sectional study, 79 women also completed the food-frequency component of the Health Habits and History Questionnaire (HHHQ), version 2.1 (72). Median estimates from this food-frequency questionnaire did not differ significantly from diet records for intakes of energy, total fat, and saturated fatty acids; and energy-adjusted estimates did not differ significantly for intakes of linoleic and oleic acid, the ratio of linoleic acid to saturated fatty acids (L:S), or fiber. (Linoleic and oleic acids, but not total polyunsaturated and monounsaturated fatty acids, are reported from the HHHQ and were estimated from 7-d diet records for purposes of comparison.) Diet-hormone relations

varied, however, depending on the dietary assessment tool used. The relations between the P:S and plasma estrogens during the luteal phase of the menstrual cycle seen with 7-d records were not apparent when analyses were performed with data from food-frequency questionnaires. Based on food-frequency questionnaires, differences in luteal-phase plasma estradiol and estrone per 0.1 increment in the L:S were, respectively,  $-3.4\%$  (95% CI:  $-8.1\%$ ,  $1.6\%$ ) and  $-0.1\%$  (95% CI:  $-4.9\%$ ,  $4.9\%$ ). Whether discrepancies reflect the imprecision of dietary-assessment tools or differences in the time interval for which diet was estimated by the food-frequency questionnaire (past year) and diet records (current) is unclear.

Although we observed some interesting relations between diet and plasma hormones in this cross-sectional study, exclusion criteria may have limited our ability to detect diet-hormone associations. Only women who were between the 85th and 130th percentile of weight-for-height, who were not following a vegetarian diet, and not routinely participating in strenuous activities were eligible for our study. Exclusion of women with more extreme weight-for-height ratios and dietary and activity patterns may have diminished variation in energy, fat, and fiber intakes, and decreased our chances of observing relations with plasma hormones.

Blood for hormone analyses was collected on days 5–7, 12–15, and 21–23 of each woman's menstrual cycle. Timing of blood collections in relation to the start of last menses, as opposed to the date of ovulation, may have increased the variance of estrogen measurements and also obscured associations with diet.

The findings of this cross-sectional study in premenopausal women support a relation between diet and plasma sex hormones. In particular, energy intake was positively associated with the probability of a rise in luteal-phase progesterone and inversely associated with plasma androgen concentrations, and polyunsaturated fat intake and the P:S of the diet were inversely associated with luteal-phase plasma estrogens. Further studies are needed to clarify the relations of diet to the plasma hormones that have been related to cancer risk. 

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